Comparison of OLR data sets from AIRS, CERES, and MERRA 2

Jae N. Lee, Joel Susskind, Lena Iredell, Norman Loeb, and Young-Kwon Lim

NASA GSFC Sounder Research Team (SRT)

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- Introduction

- OLR comparison from AIRS, CERES, and MERRA 2

  1. Climatologies
     （OLR, clear sky OLR, LW cloud radiative forcing)
  2. Anomalies
     (Average Rate of Changes (ARCs) and
     El Niño correlations (ENCs))

- AIRS vs CERES : There is a bias of ~3.5W/m^2 in OLR, which is nearly constant both in time and space.
- AIRS/CERES vs MERRA 2 : Biases are noticeable in cloudy regions.

AIRS Version-6 Level-3 Products Used

- OLR and OLRclr are computed by the Radiative Transfer Algorithm (*Iacono et al*., 2008) for 16 spectral bands with the AIRS retrieved geophysical parameters (*i.e., Ts, T(p), O_3(p), CO_2(p), H_2O(p), cloud height, and cloud fraction*) for a given scene.
- Derived independently from CERES, AIRS OLR and spectral OLR are being used for climate studies.
- Diurnal difference is achieved by the difference from ascending (1:30PM) and descending (1:30AM) orbit (Susskind et al., 2016a, 2016b, in preparation).
- Cloud spectral emissivity is assumed to be gray in the OLR calculation, this is not true for cirrus clouds.

CERES EBAF Edition 2.8 Products Compared

- OLR is primarily a measured quantity using broad banded observation taken at a single zenith angle.
- TOA OLR is balanced and filled to adjust SW and LW TOA fluxes to reduce the imbalance in the net flux.
- EBAF Edition 2.8 uses only Terra CERES (not Aqua), but uses GEO to fill the cloud and radiation information between CERES observations.

MERRA 2 Compared
(Modern-Era Retrospective Analysis for Research and Applications-2)

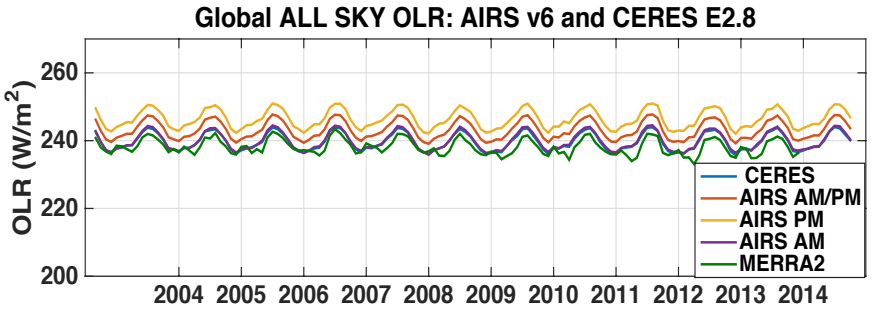
- Newly released version of NASA/GMAO MERRA with algorithm updates [Molod et al., 2015]
- High spatial resolution product : 0.625^{o}(lon) by 0.5^{o}(lat) since 1980
- OLR radiative processes are from Chou and Suarez [1994]
- Polar land processes are added, improved over GrIS and Antarctica

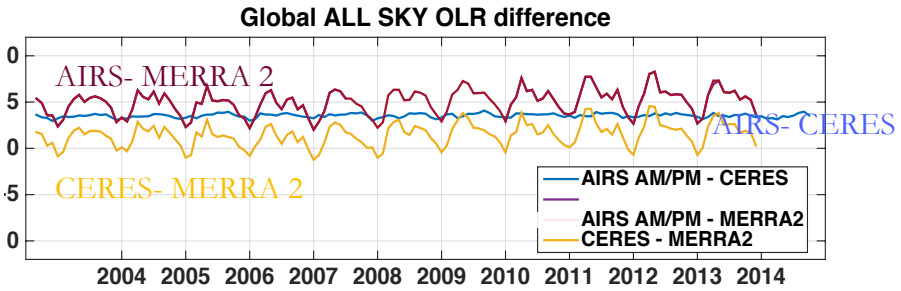
Part 1

Comparison of OLR Time Series and Climatologies

- CERES, AIRS, and MERRA 2 climatologies are based on the same 11 consecutive years (September 2002 through August 2013)
- For AIRS, 1:30 PM and 1:30 AM level-3 monthly mean, 1°x1° gridded OLR and clear sky OLR (OLRclr) products are analyzed separately from each other.
- Daily averaged values are calculated as a mean of two local time (AM/PM) observations.

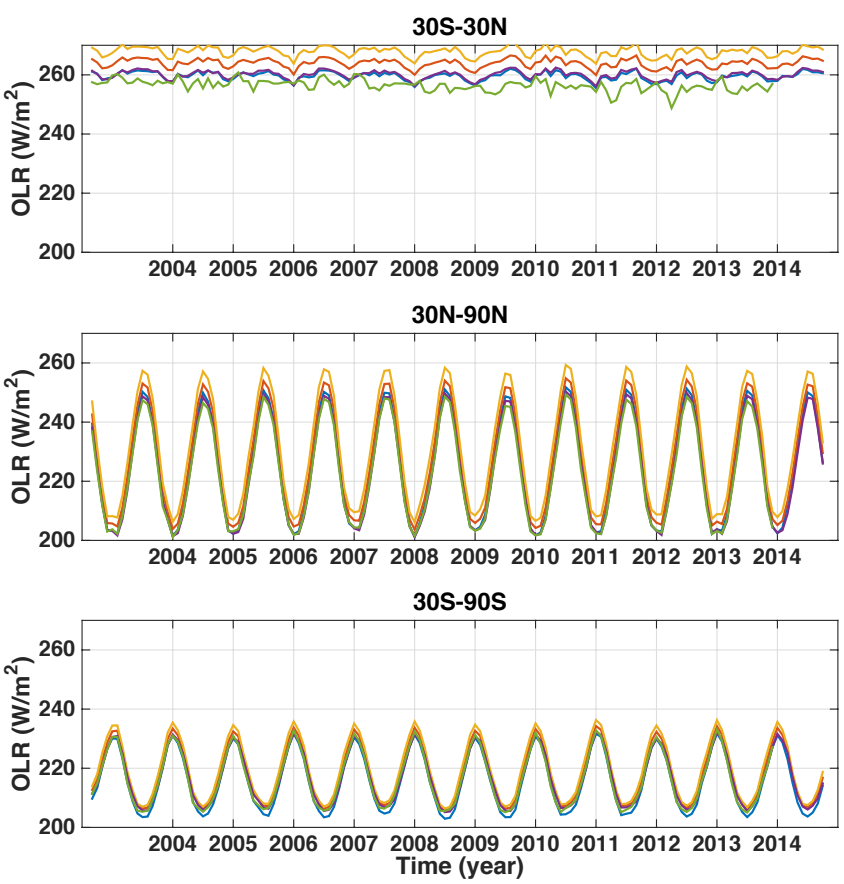
Global Mean OLR Time Series (W/m^2)

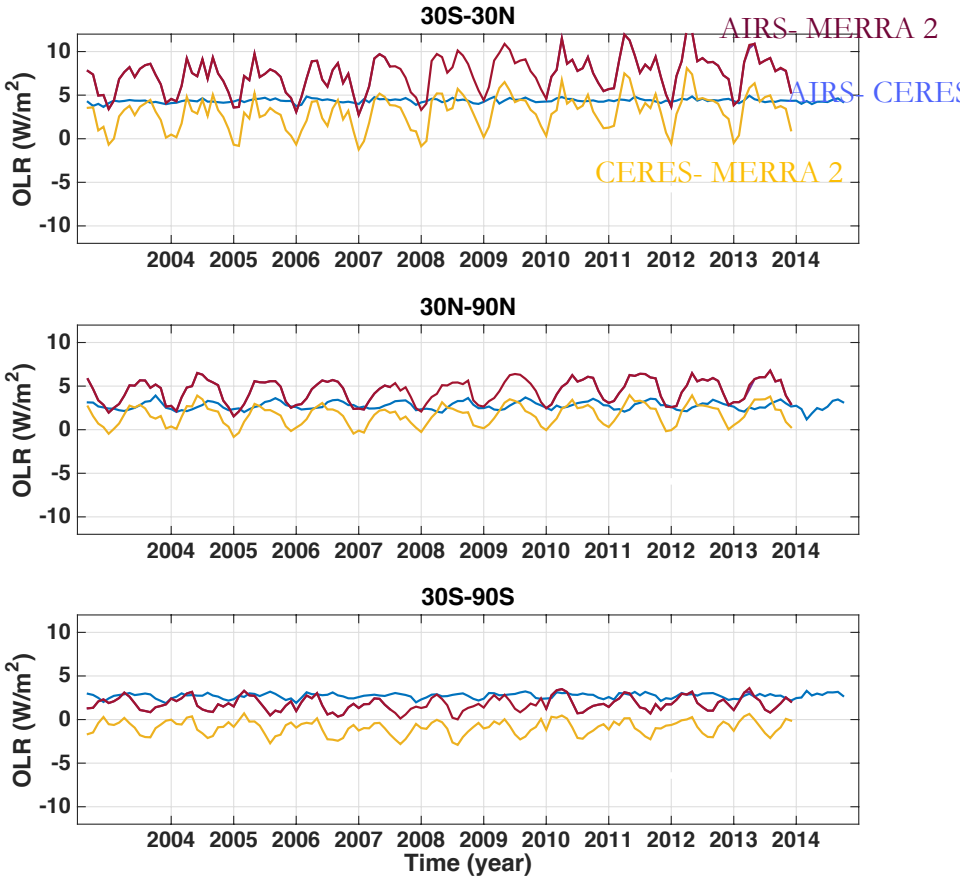




- OLR is time of day dependent.
- Global mean OLR is ~7W/m^2 higher at 1:30 PM than 1:30 AM :
  Details in regional difference will be discussed in Susskind et al., (2015a).
- CERES global mean OLR closely matches AIRS 1:30 AM values.
- AIRS/CERES OLR global mean difference is ~3.5W/m^2, and roughly constant over the 11 yrs.
- AIRS/MERRA2 and CERES/MERRA2 differences have a seasonal cycle.

Area Mean OLR Time Series (W/m^2)





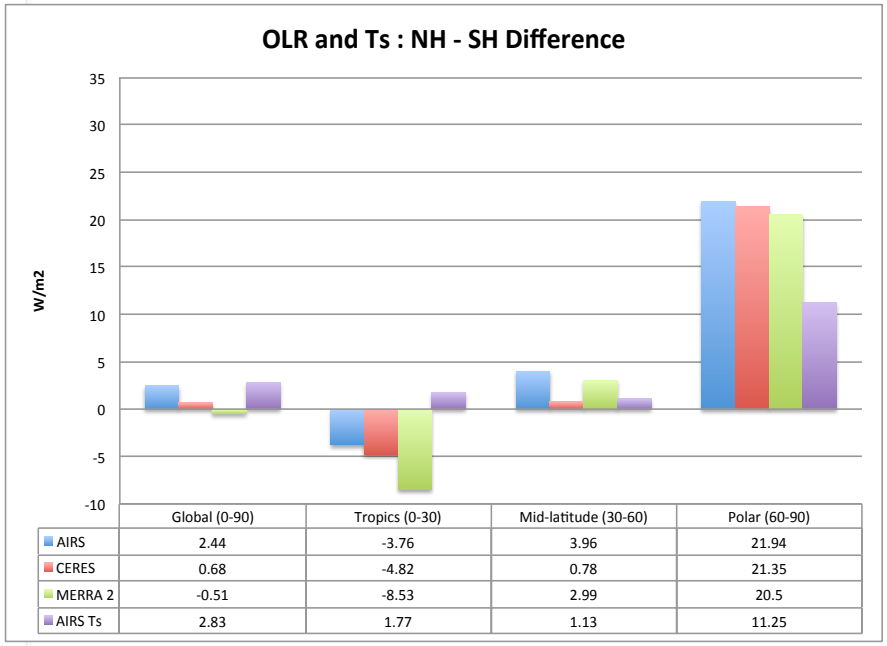
- CERES global mean OLR closely matches AIRS 1:30 AM values, it is also true in the tropics, and extra tropics during summer.
- OLR is ~9W/m^2 higher in NH extratropics than SH extratropics
- In SH, AIRS OLR is higher.

Differences Between AIRS and CERES OLR Time Series (W/m^2)

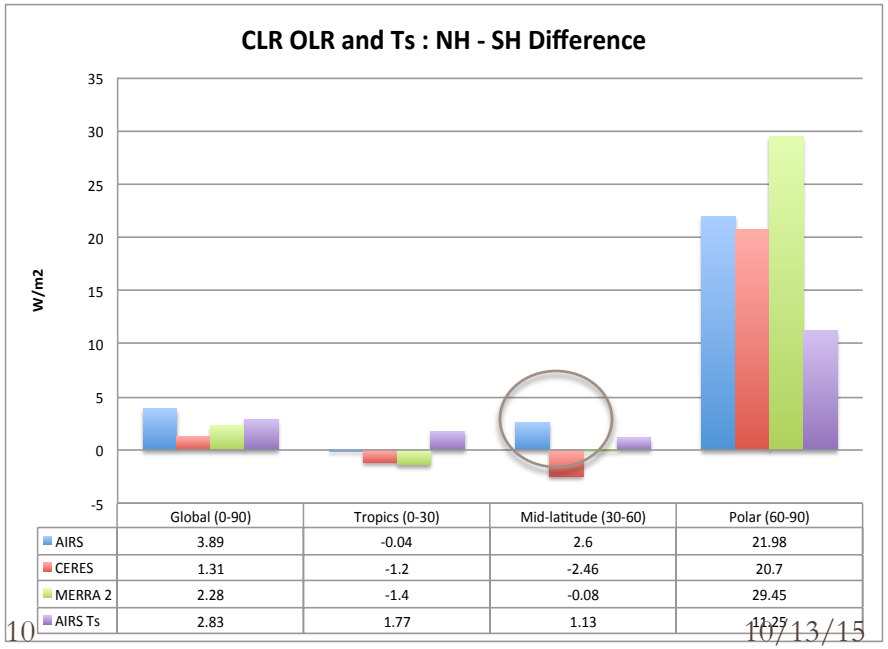
	AIRS 1:30AM minus CERES	AIRS 1:30PM minus CERES	AIRS 1:30PM/AM minus CERES
Global Mean			
Bias	0.29	6.77	3.53
STD	0.24	0.33	0.22
Slope ($W/m^2/yr$)	0.0133±0.0111	0.0042± 0.0160	0.0086±0.0103
Tropical Mean			
Bias	0.44	8.23	4.35
STD	0.35	0.34	0.24
Slope ($W/m^2/yr$)	0.0256±0.0157	0.0012±0.0166	0.0132±0.0106
30N-90N Mean			
Bias	-1.13	6.63	2.75
STD	0.98	1.00	0.46
Slope ($W/m^2/yr$)	-0.0182±0.0475	0.0146±0.0487	-0.0020±0.0222
30S-90S Mean			
Bias	1.37	4.08	2.73
STD	0.85	0.48	0.30
Slope ($W/m^2/yr$)	0.0204±0.0411	-0.0003±0.0277	0.0100±0.0140

Hemispheric Asymmetry in OLR and OLR_{CLR}

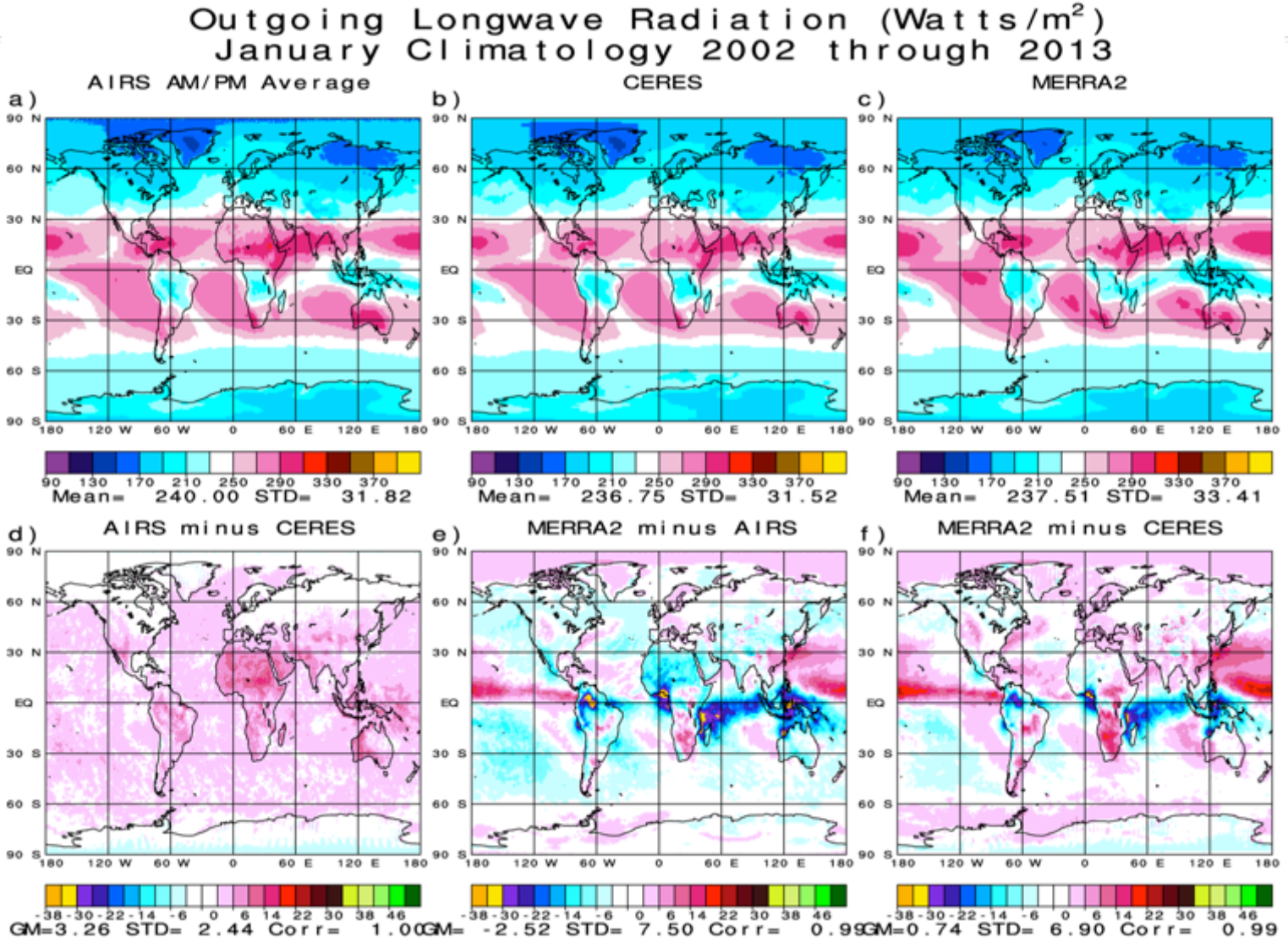
- Hemispheric asymmetry is largest at polar region.
- NH Ts is warmer, especially in polar region.
- NH winter gets more solar radiation.
- SH is cloudier.



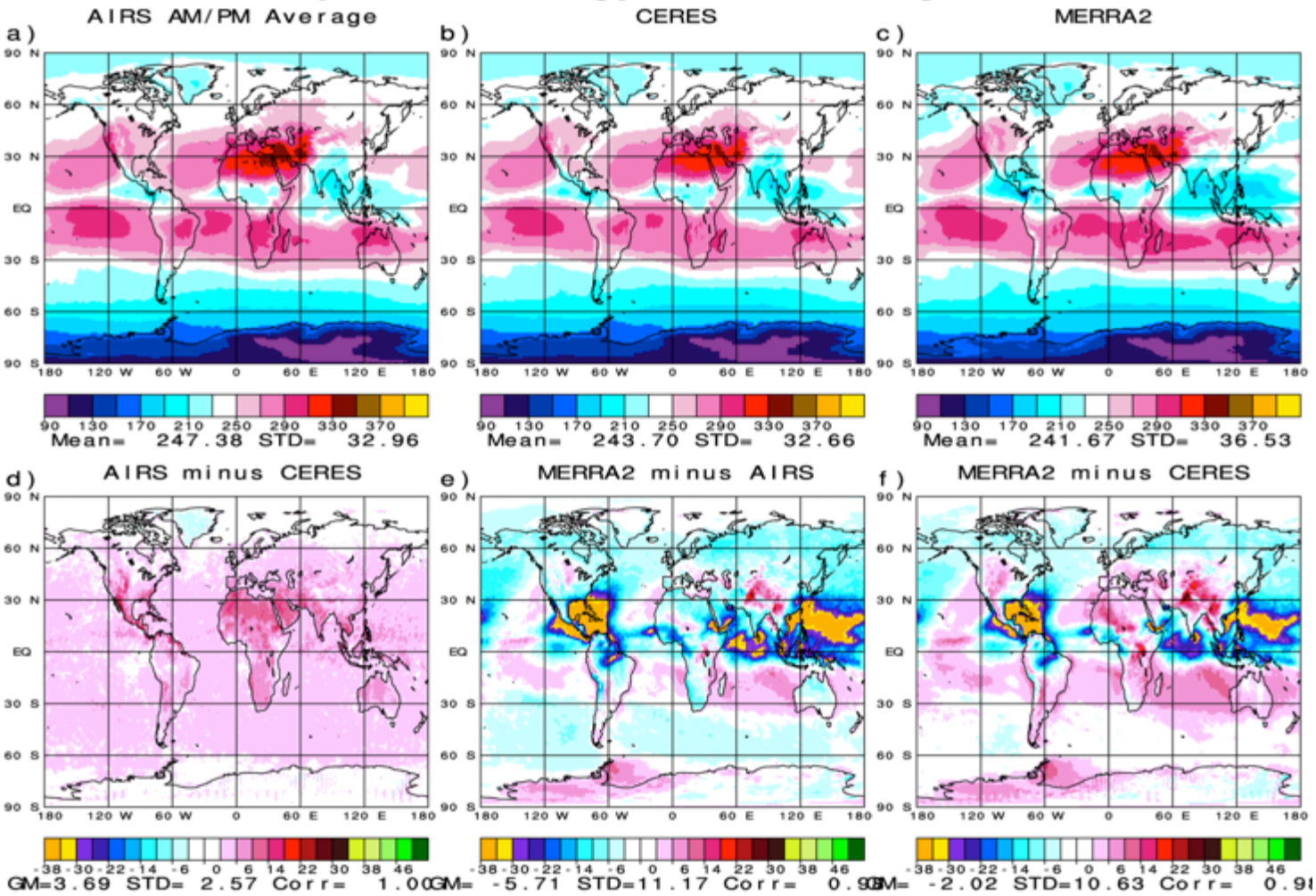
	Global (0-90)	Tropics (0-30)	Mid-latitude (30-60)	Polar (60-90)
AIRS	2.44	-3.76	3.96	21.94
CERES	0.68	-4.82	0.78	21.35
MERRA 2	-0.51	-8.53	2.99	20.5
AIRS Ts	2.83	1.77	1.13	11.25



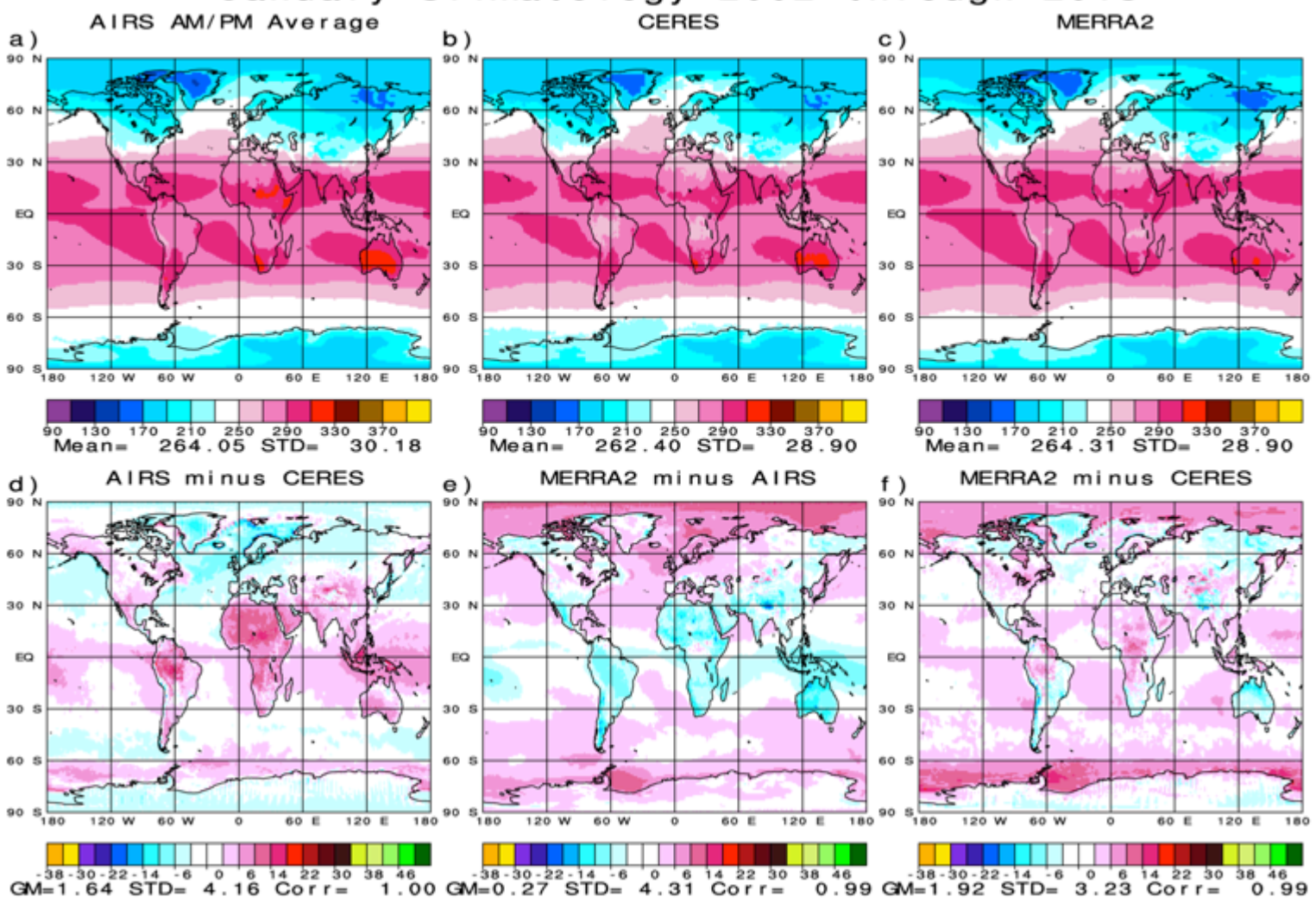
	Global (0-90)	Tropics (0-30)	Mid-latitude (30-60)	Polar (60-90)
AIRS	3.89	-0.04	2.6	21.98
CERES	1.31	-1.2	-2.46	20.7
MERRA 2	2.28	-1.4	-0.08	29.45
AIRS Ts	2.83	1.77	1.13	11.25



- AIRS AM/PM averaged OLR is higher compared to CERES every where, but the biases reflect AIRS day/night difference pattern.
- MERRA 2 values are lower over tropical mid-high cloud covered region, than AIRS/CERES.



- AIRS/CERES differences in July are similar to those in January.
- Differences in MERRA 2 are outstanding over western Atlantic and Pacific.



- Even more different sampling and methodology in AIRS and CERES OLRclr.
- Unlike CERES, AIRS OLRclr does not require the scene to be clear, 80% of all observed by AIRS are included.
- Unlike OLR, the biases are region dependent.

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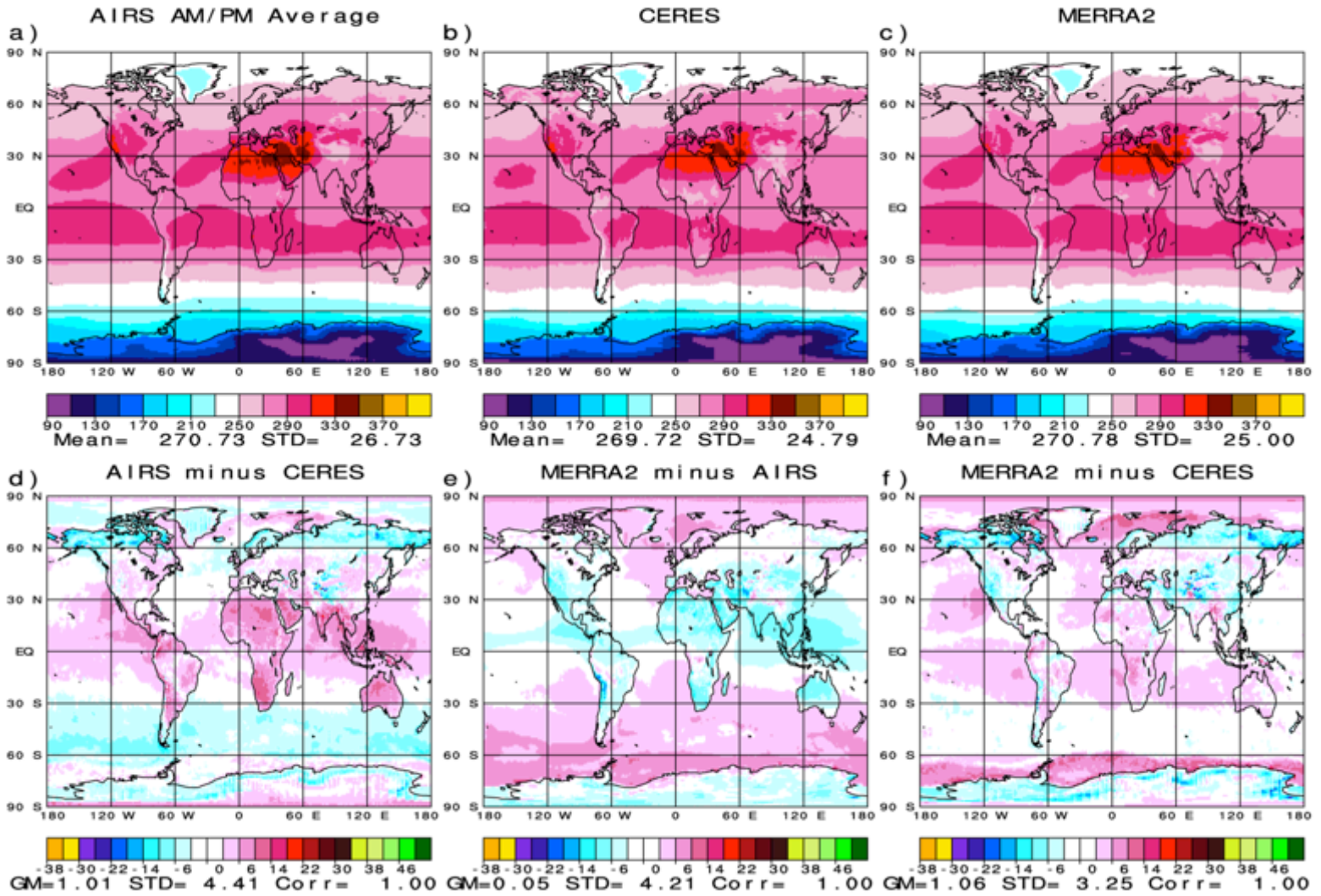
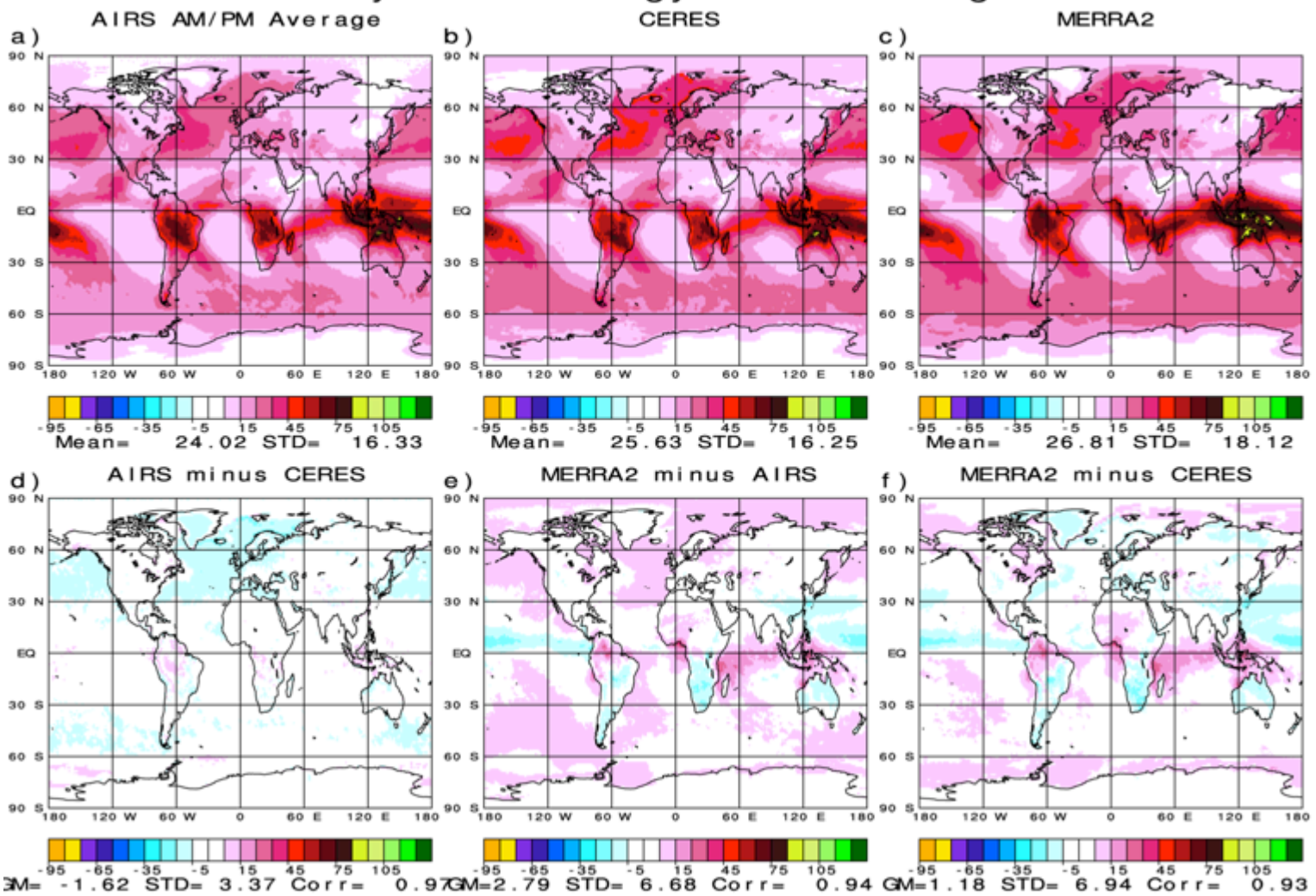
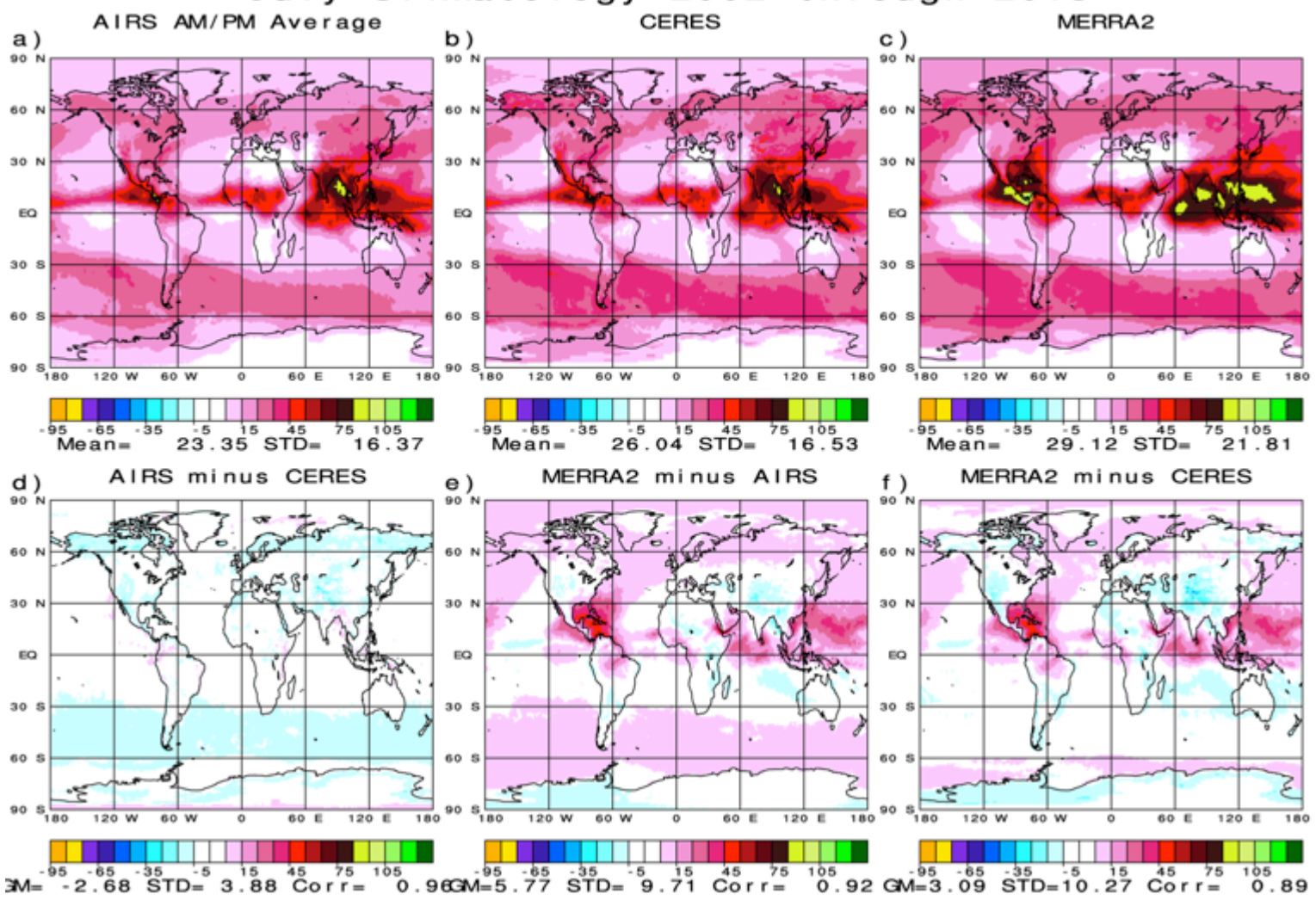


- Similar to January, the difference patterns are complex.
- Diurnal differences are larger over land during summer, these cause the contrast in AM and PM difference patterns. Bias pattern between AIRS and CERES is close to AM and PM difference patterns.



- The LWCRF is up to 75 W/m^2 over the tropics.
- AIRS values are lower throughout extra-tropical storm track regions polewards of 35 degrees, especially in the winter hemisphere.
- By the passage of cold front, it is cold and cloudy in general. AIRS sampling over those regions may cause low OLRclr values.



- In MERRA 2, cloud forcing is higher in cloudy regions.

Part 2
Comparison of AIRS, CERES, and MERRA 2 OLR in Anomalies

- Agreement in three data sets are valuable to assess the near term trend and inter annual variabilities in OLR and LWCRF (Susskind et al., 2016b).

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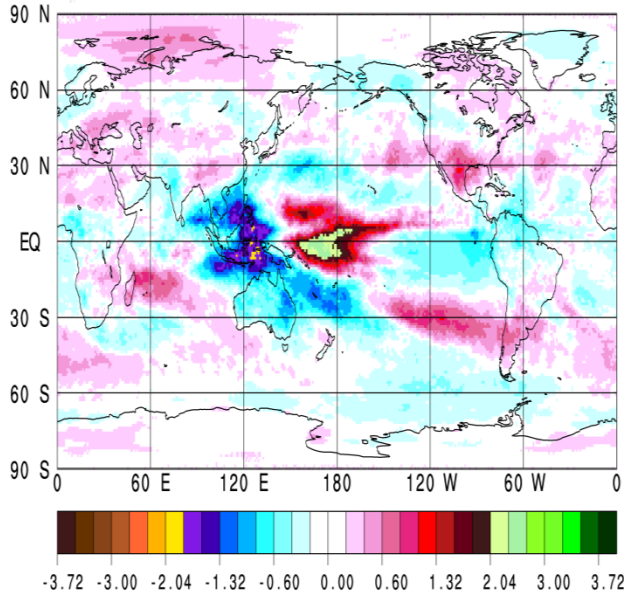
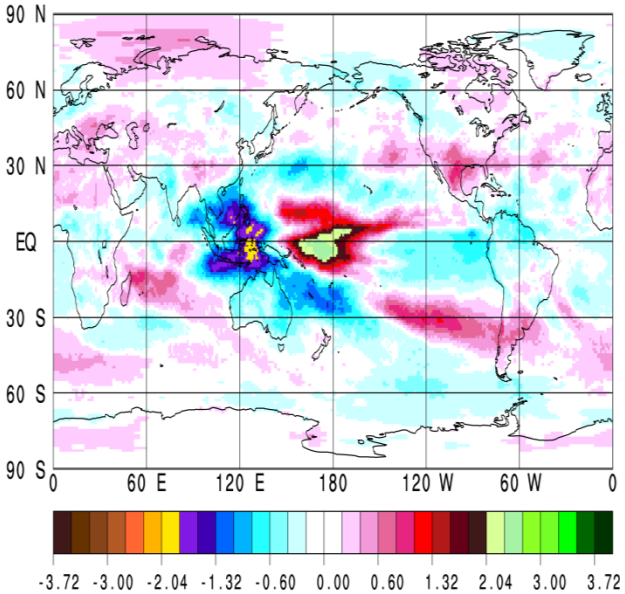
OLR Average Rates of Change (ARC) September 2002 through December 2013

AIRS



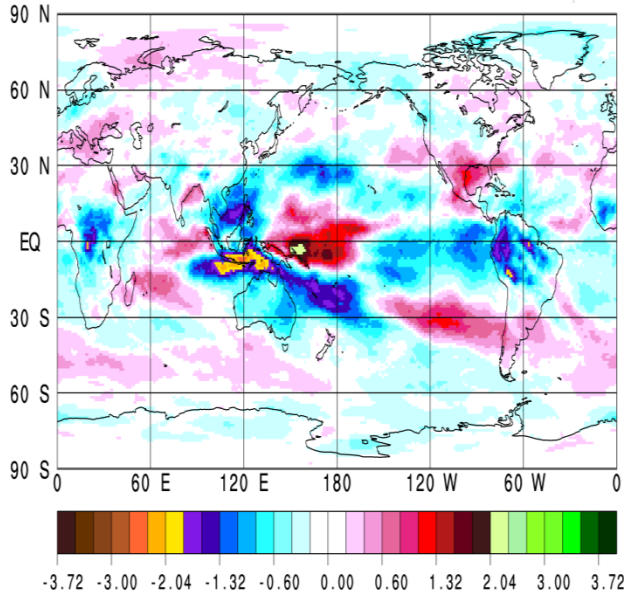
Global Mean = -0.027 STD = 0.488

CERES



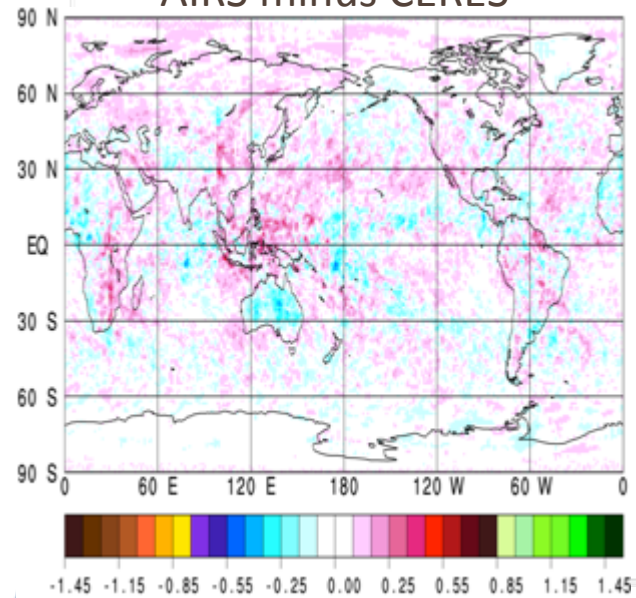
Global Mean = -0.041 STD = 0.501

MERRA2



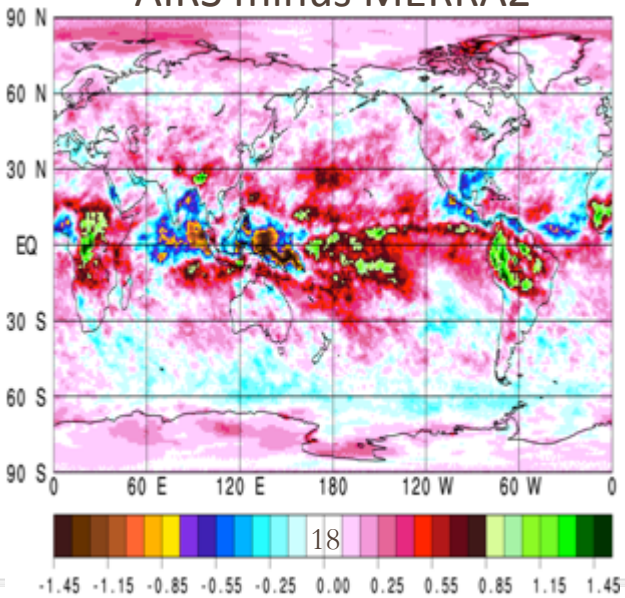
Global Mean = -0.142 STD = 0.544

AIRS minus CERES



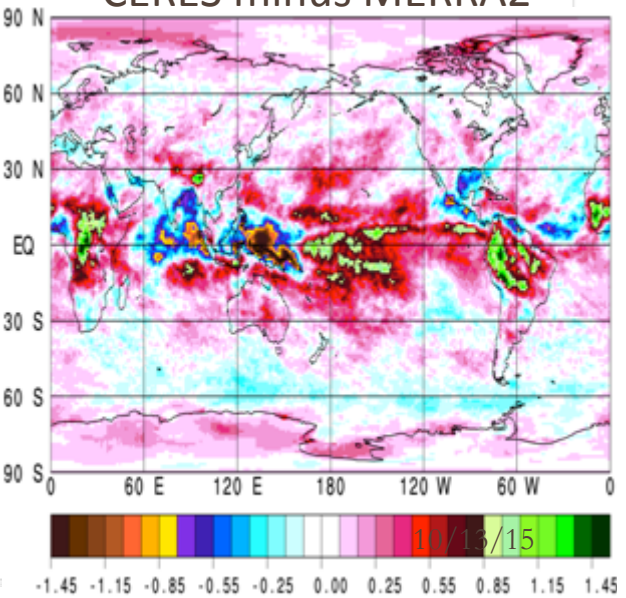
GM = 0.013 STD = 0.093 Cor=0.980

AIRS minus MERRA2



GM = 0.115 STD = 0.337 Cor=0.797

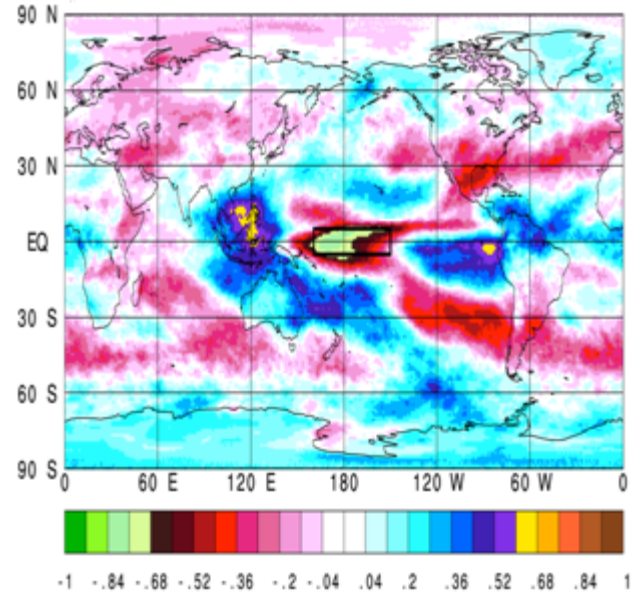
CERES minus MERRA2



GM = 0.101 STD = 0.334 Cor=0.805

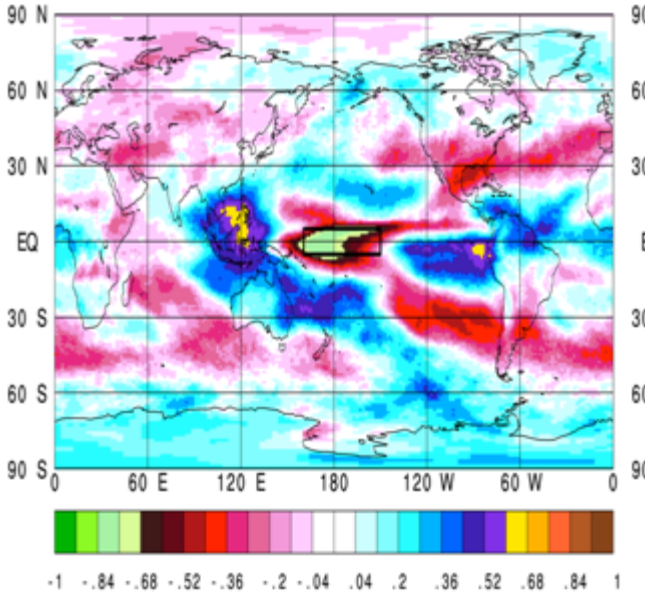
OLR El Niño Correlation (ENC) September 2002 through December 2013

AIRS



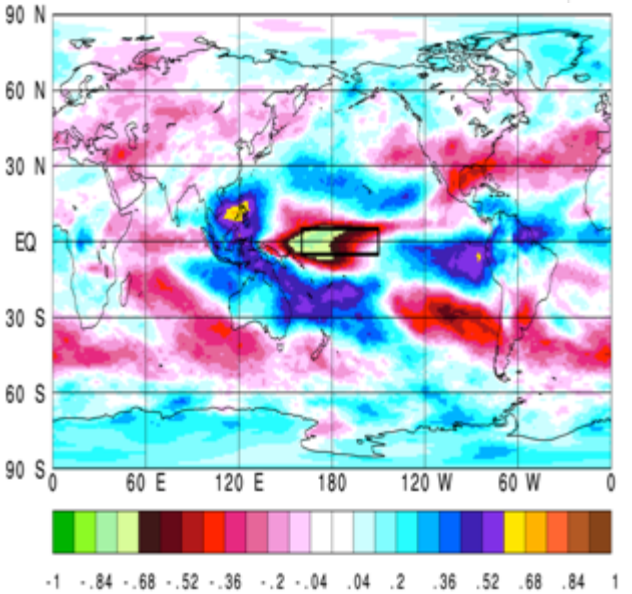
Global Mean = 0.018 STD = 0.244

CERES



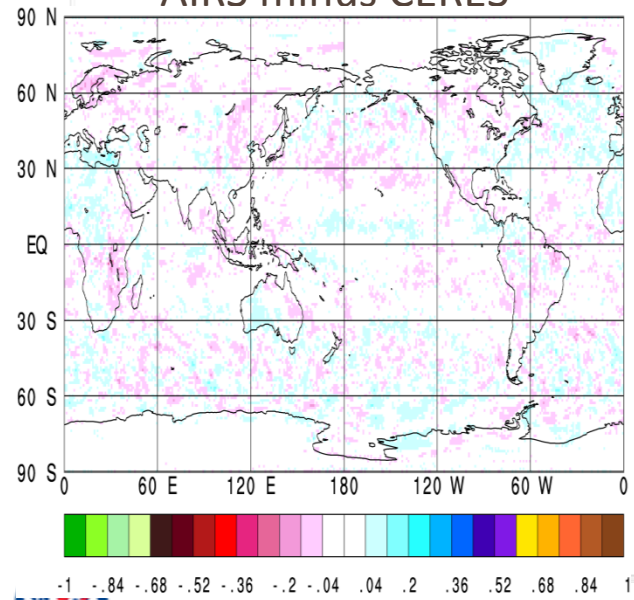
Global Mean = 0.020 STD = 0.249

MERRA2



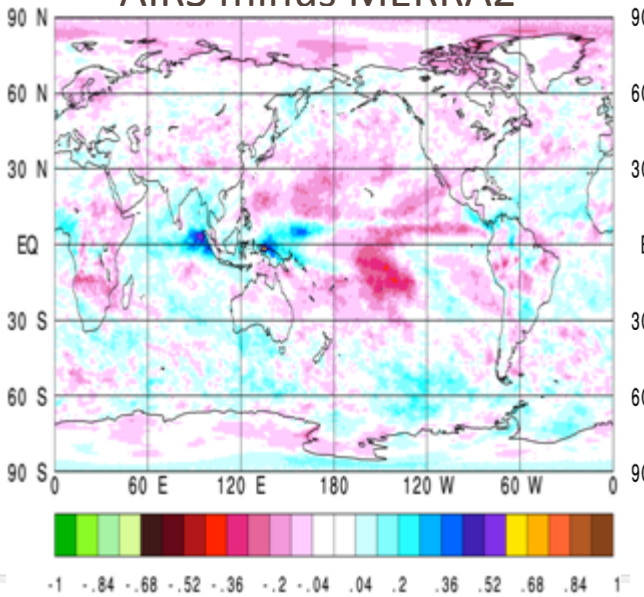
Global Mean = 0.022 STD = 0.246

AIRS minus CERES



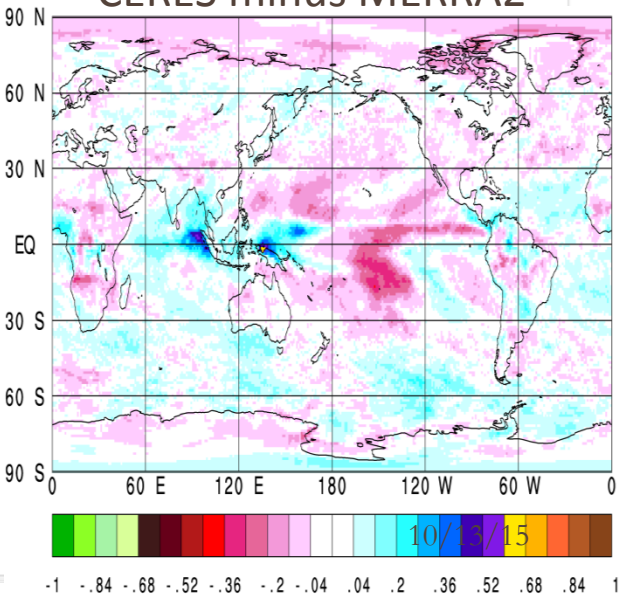
GM = -0.002 STD = 0.036 Cor=0.986

AIRS minus MERRA2



GM = -0.004 STD = 0.092 Cor=0.921

CERES minus MERRA2



GM = -0.002 STD = 0.089 Cor=0.928

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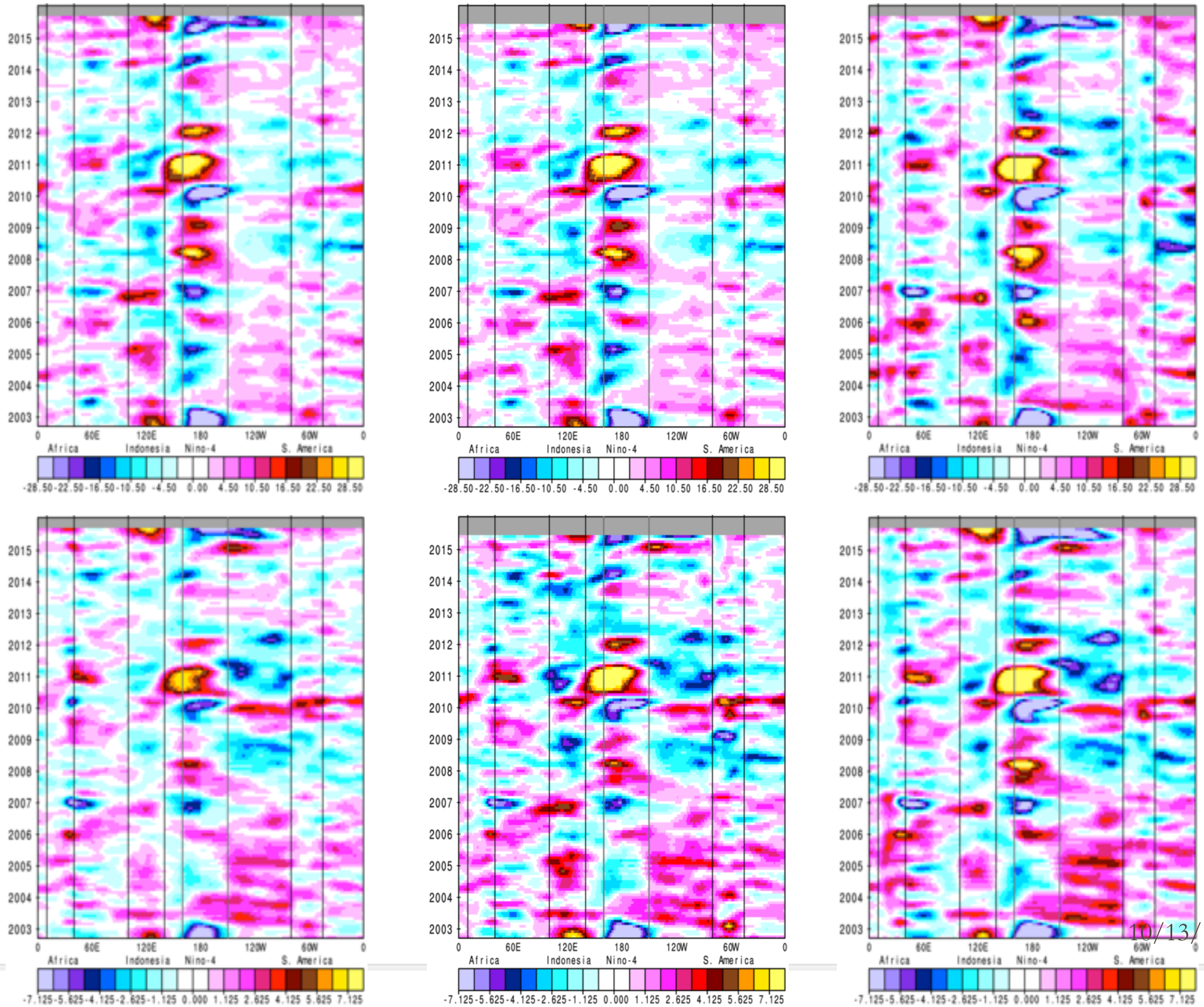
Hovmöller Diagram Tropics 5°N to 5°S

AIRS | CERES | MERRA-2

OLR (W/m^2)

Clear Sky OLR (W/m^2)



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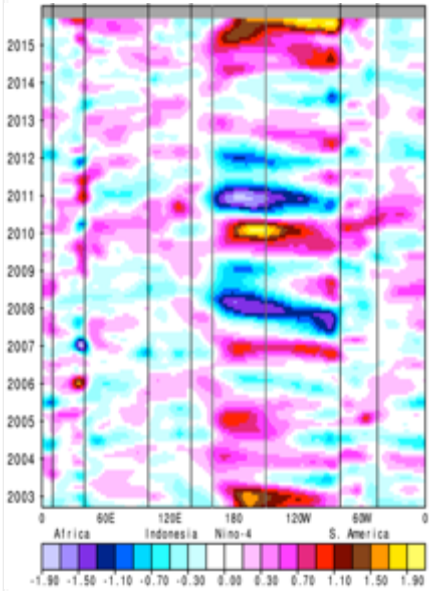
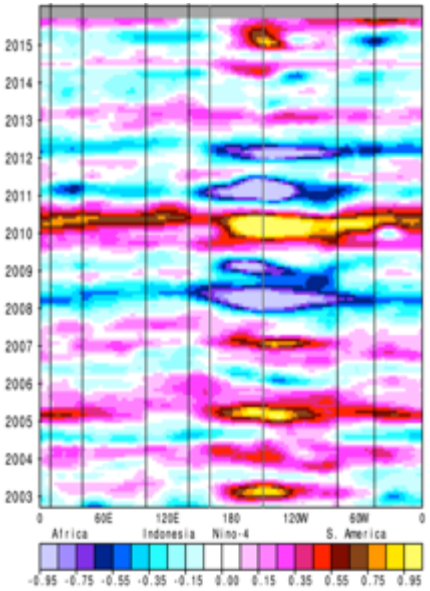
AIRS and MERRA 2 Hovmöller Diagram (Tropics 5°N to 5°S)

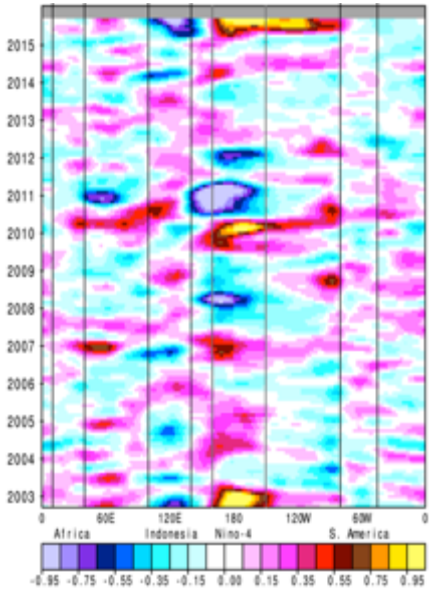
a)Surface Skin Temp (K)



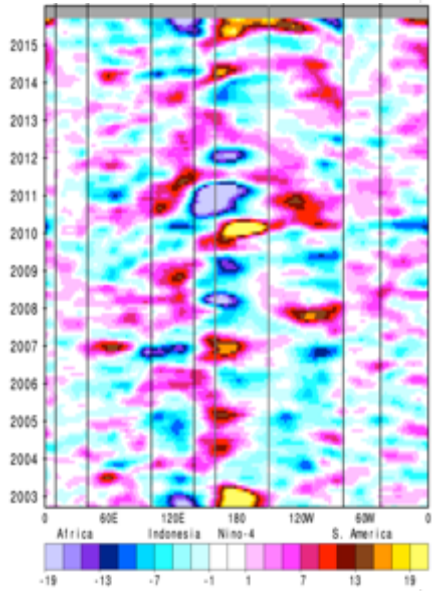
b) 500 mb Temp (K)

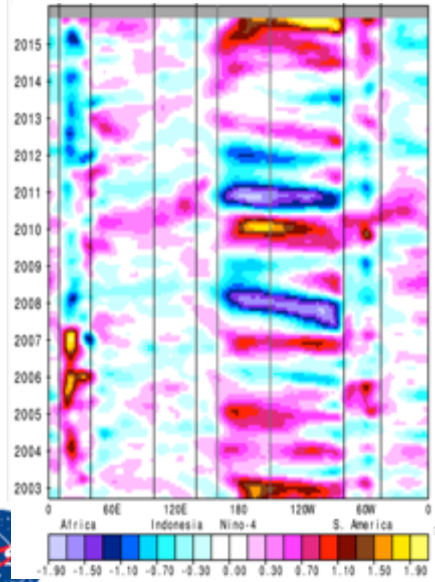


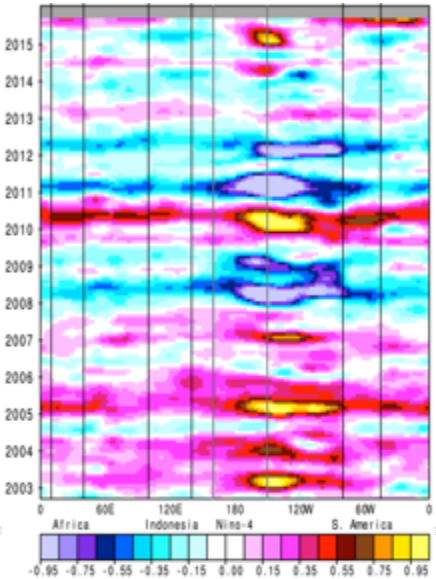
c)500 mb Specific Humidity

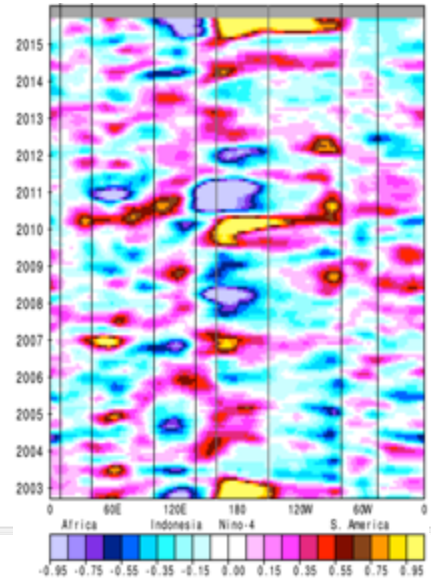


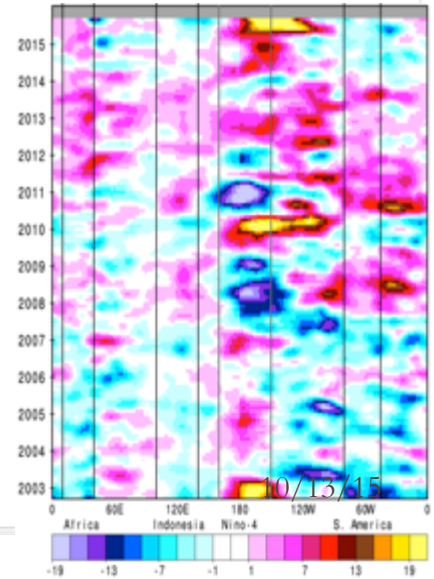
d) Cloud











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Correlations of Hovmöller Diagram : OLR (OLRclr)

	AIRS OLR (OLRclr)	CERES OLR (OLRclr)	MERRA 2 OLR (OLRclr)
AIRS OLR (OLRclr)		0.98 (0.88)	0.82 (0.93)
CERES OLR (OLRclr)	0.98 (0.88)		0.81 (0.88)
OLR vs OLRclr	0.72	0.80	0.88

Correlations of variables (AIRS and MERRA 2)

Skin Temp	Temp (500mb)	q (500mb)	cloud fraction
0.82	0.89	0.95	0.38

Summary

- AIRS Version-6 OLR matches CERES Edition-2.8 OLR very closely on a 1°x1° latitude x longitude scale, both with regard to absolute values, and also with regard to anomalies of OLR. There is a bias of ~3.5W/m^2, which is nearly constant both in time and space.
- Contiguous areas contain large positive or negative OLR difference between AIRS and CERES are where the day-night difference of OLR is large. For AIRS, the larger the diurnal cycle, the more likely that sampling twice a day is inadequate.
- MERRA 2 captures the similar patterns of climatology and interannual variability, but the comparison between AIRS/CERES is closer than the comparison with MERRA 2.
- Lower values of OLRclr and LWCRF in AIRS compared to CERES is at least in part a result of AIRS sampling over cold and cloudy cases.

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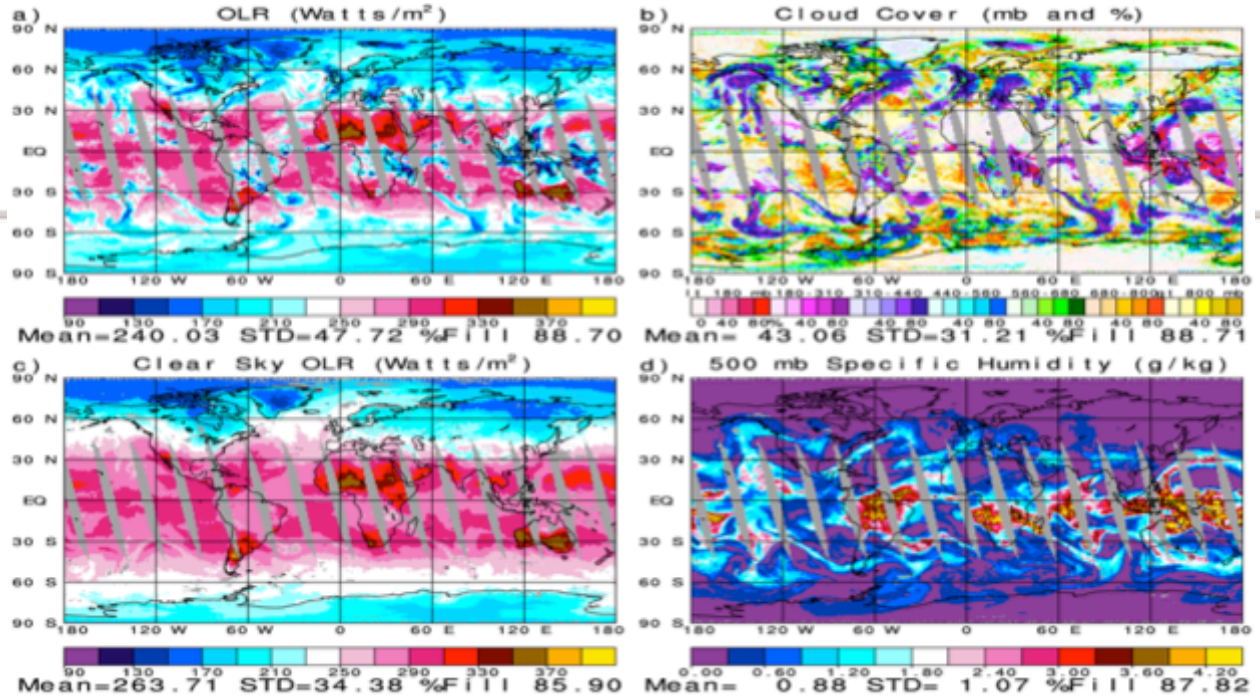
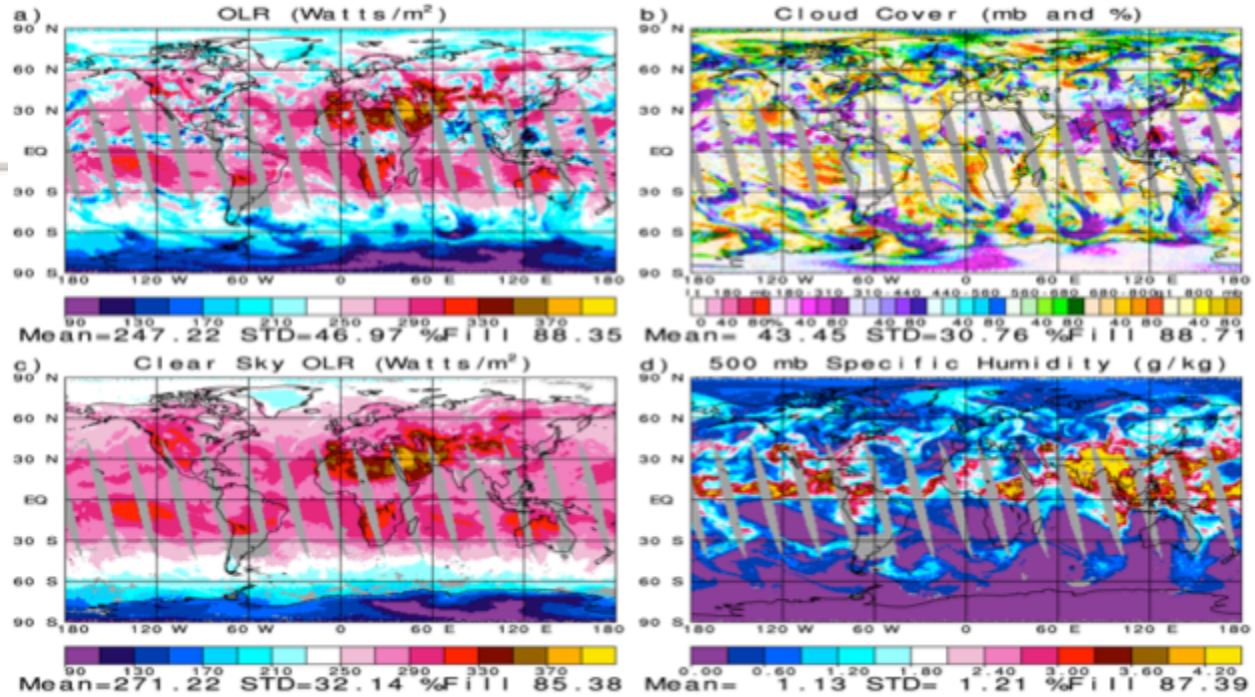
Back ups

Daily fields : AIRS Version-6 January 15, 2014 1:30 PM



- About 89% of grids are covered in a single time period. About 96% of those grids were contained values for OLRclr.
- OLRs are low (high) where the surface skin temperature is low (high).
- OLRs are low where mid-high level clouds exist, where 500 mb specific humidity is also high.
- This lowers clear sky OLR in these regions as well.

Daily fields : AIRS Version-6 July 15, 2014 1:30 PM



- Correlation among OLR, surface skin temperature, clouds, and humidity are identical with NH winter, but the cloud pattern is different in two seasons.